National Aeronautics and Space Administration

Cryogenic Analysis Tool: Applied to the Lunar Surface Access Module

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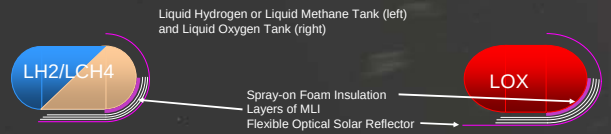
Project Overview

Introduction:

- Stored cryogenic propellants vaporize as heat is absorbed and vent to space (boil-off)
- Boil-off necessitates augmented fuel storage for desired capability
- Excess fuel tank solution only applicable to short duration applications
- Zero (or reduced) boil-off systems offer mass savings for Moon and Mars missions

Cryogenic Analysis Tool:

- CAT predicts overall system mass: fuel, boil-off, tank, insulation, and cooling system components
- Determines heat leak based on tank & strut geometries, construction materials, line sizes, pressure relief systems, and insulation methods
- Returns data useful to component design and sizing based on specific mission parameter inputs

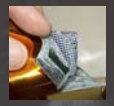


Purpose:

- CAT determines optimal strategy for storing cryogenic propellants of LSAM or other missions
- Analysis of collective or independent mission segments yields useful design specifications
- Cryogenic storage system analysis is vital for development of long duration space vehicles

Current Use

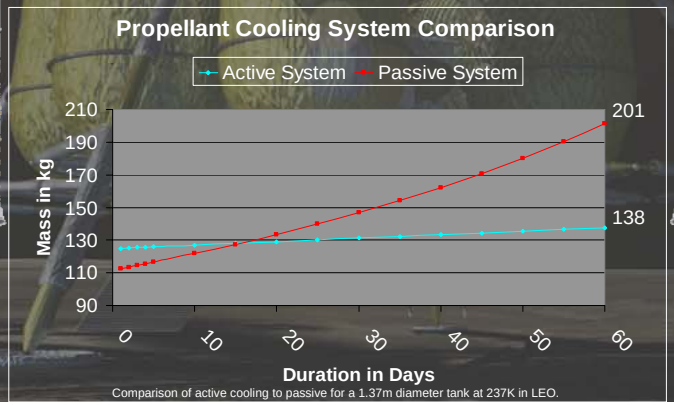
Passive Thermal Control:



- Properly designed thermal control system conserves mass on short duration flights
- CAT analysis performed on all elements that add heat to tank- through insulation and penetrations
- Boil-off increases in direct proportion to heat load
- To compensate for propellant lost as boil-off, tanks are oversized. Increased tank size also raises heat absorption generating even more boil-off
- CAT's iterative calculations resize tank for optimum propellant storage system mass

Active Cooling:

- Cryocooler system ultimately requires less mass than passive tank resizing on long duration spaceflight
- CAT sizes cryocooler, radiator, solar arrays, helium cooling tubes for active cooling system
- Calculates component masses, heating rates, and power consumption for reduced boil-off conditions



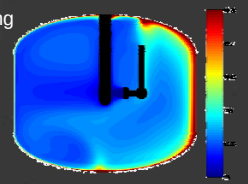
Comparison of active cooling to passive for a 1.37m diameter tank at 237K in LEO.

Further Application

Individual Contributions:

- Primary development of parametric capability added to CAT via VBA modules
- Speed of calculation and accuracy improved in existing calculations via VBA
- Penetration heat leak calculations implemented based on tank scaling and construction material
- Input parameters now generate scale images of tank specifications and designs

Future Development:



- More detailed tank penetration heating
- Create penetration heating database
- Integrated shade design
- Thermal testing
- Hydrogen temperature shield
- Validation

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